Endurance Measurement in Older Adults: A Systematic Exploration of Assessment Tests and Properties

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Purpose This systematic review aims to comprehensively identify and analyze assessment tests for measuring muscle and cardiopulmonary endurance in individuals aged 65 and above. The focus is on providing a detailed account of the measurement properties and practical aspects of these tests. ***Methods*** A systematic and rigorous search was conducted in the PubMed database, with a focus on articles published in English and Korean within the last 5 years. Inclusion criteria were carefully crafted to encompass clinical trials and randomized controlled trials, ensuring a thorough and up-to-date selection process. ***Results*** Out of the initial pool of 156 articles, 23 studies successfully met the inclusion criteria. These studies collectively evaluated eight distinct assessment tests for endurance in older adults, with the 6 Minute Walk Test (6MWT) emerging as the most prevalent. Beyond mere prevalence, the review delves into the reliability of the widely used 6MWT, providing a nuanced understanding of its practical implications. ***Conclusion*** This systematic review sheds light on the plethora of available endurance assessment tools for older adults, emphasizing the critical need for informed selection based on specific criteria. The inclusion of a summary table offers a quick reference guide for clinicians and researchers, facilitating the selection of appropriate assessment tools tailored to individual needs and study objectives.

Key Words Aerobic endurance, Muscular endurance, Measurement tools, Older adults

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Ⅰ. Introduction

As the global population undergoes a profound demographic shift, characterized by a remarkable increase in older individuals, the imperative to promote healthy aging has never been more critical.[1)] Central to this endeavor is the preservation of physical resilience, particularly in the domains of muscle and cardiopulmonary endurance. Endurance, encompassing the capacity to sustain physical activities over time, is intricately linked to an individual's ability to maintain independence and quality of life as they age.[2,3)]. The decline in physical performance with age, affecting approximately 33% of individuals aged 65 or older, has far-reaching consequences, compromising daily activities and contributing to the escalating healthcare burden associated with aging populations.[2,4)]

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The assessment of endurance in older adults is a complex task that demands a comprehensive approach. In contemporary healthcare, a plethora of assessment instruments including notable tests such as the 6 Minute Walking Test (6MWT), 2 Minute Step Test, and isometric contraction methods.[5,6)] Notably, these instruments exhibit variations in their functional applications, content, and inherent characteristics. Moreover, the diversity in these tools, ranging from simple clinical measures to sophisticated performance tests, introduces challenges in selecting the most suitable option.

The absence of a unanimous consensus on the optimal assessment test underscores the complexity of selecting a singular, universally accepted tool. This lack of consensus prompts a critical consideration of the diverse factors influencing the choice of assessment methods. While this diversity may present challenges, the importance of selecting an accurate assess-

ment tool cannot be overstated.[7] Precision in test selection enhances the thoroughness of evaluations and plays a pivotal role in formulating precise care plans, thereby contributing significantly to monitoring progress over time.[8]

However, the abundance of available assessment tools introduces a complex decision-making process for clinicians and researchers, necessitating a judicious selection process aligned with the unique characteristics of the aging population. Navigating the diversity in methods requires a systematic and informed approach to ensure that the chosen tools not only align with the objectives of the assessment but also exhibit robust measurement properties.[9] Validity, reliability, and practicality are paramount considerations in this context, demanding careful scrutiny of each assessment tool's inherent characteristics.[10]

In response to the intricate challenges posed by declining endurance in older adults and the array of assessment tools available, this systematic review aims to provide a comprehensive examination of recent literature. By focusing specifically on individuals aged 65 and above, the review seeks to identify, analyze, and distill the essence of assessment tests designed to measure muscle and cardiopulmonary endurance in this demographic. Therefore, the objectives of this systematic review are threefold: (i) To comprehensively identify the most recent and commonly used assessment tests specifically designed for evaluating muscle and cardiopulmonary endurance in older adults; (ii) To provide an in-depth examination of the measurement properties associated with each identified assessment test, encompassing factors such as validity, reliability, and practicality; (iii) To synthesize the findings into a valuable reference guide, offering clinicians and researchers a nuanced understanding of the characteristics of each assessment test. This guide aims to facilitate informed decision-making in selecting the most appropriate tools based on the specific objectives and constraints of individual studies.

II. Materials and Methods

2.1 Research Design

This study adheres to the guidelines outlined in the Cochrane Handbook for Systematic Reviews of Diagnostic Test Accuracy. The objective is to conduct a systematic review to identify and analyze endurance measurement tools specifically designed for older adults (aged 65 and above).

2.2 Inclusion and Exclusion Criteria

Inclusion criteria are as follows: (i) Studies published within the last 5 years to ensure a contemporary overview; (ii) Only studies with free full-text accessibility (freely available in full-text on PubMed) were considered; (iii) Clinical Trials and Randomized Controlled Trials were included, focusing on robust experimental designs; (iv) Participants aged 65 years or above to specifically target the older adult population; (v) Studies published in English and Korean were included to capture a broad range of available literature.

Exclusion Criteria are as follows: (i) Systematic reviews, meta-analyses, and retrospective studies, such as case-control studies, to maintain a focus on primary research; (ii) Studies without original content or diagnostic information, ensuring relevance to endurance measurement tools; (iii) Studies not providing sufficient information for fall risk assessment tool's diagnostic accuracy computation, emphasizing methodological rigor; (iv) Studies with participants below the age of 65 to maintain the study's focus on the older adult population.

2.3 Literature Search

A systematic literature search was conducted in the PubMed library in September 2023 to identify relevant studies. The search used the following terms: "endurance test and older adult." Filters were applied to include only studies aligning with the specified inclusion criteria.

2.4 Data Extraction

The initial search conducted in September 2023 yielded a total of 156 articles. After removing duplicates,

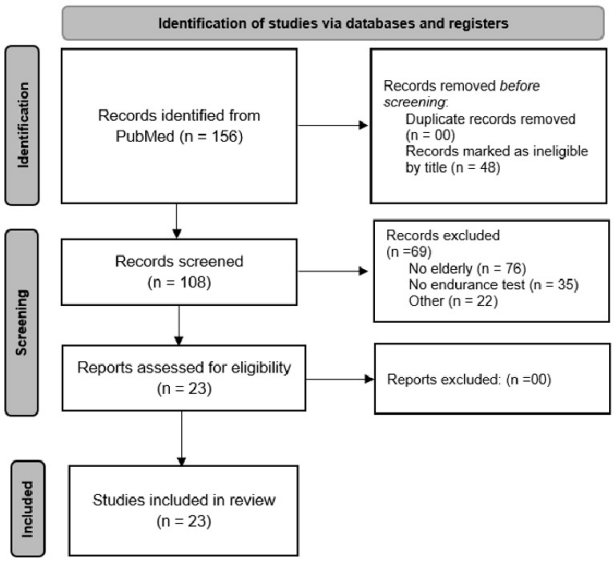

Figure 1. Research flow diagram

the titles and abstracts of 151 articles were screened to assess their appropriateness. Difficult judgments were resolved by reviewing the main text. Ultimately, 133 articles were excluded, with the common reasons including the exclusion of individuals aged 65 and above, lack of endurance measurement, specific health conditions, protocol studies, and articles not meeting the inclusion criteria. The remaining 23 articles were selected for a detailed review.

2.5 Study Selection Process

The study selection process involved a careful examination of titles, abstracts, and main texts, applying the inclusion and exclusion criteria. The criteria were independently reviewed by two researchers, with consensus determination. In cases of disagreement, a third researcher was consulted to ensure rigorous selection.

Ⅲ. Results

A total of 156 articles were initially retrieved from the electronic database, and after a meticulous screening process, no duplications were identified since the search was conducted on a single database. The titles and abstracts of the 156 articles were scrutinized to assess their suitability for inclusion. In cases where a conclusive decision proved challenging based on the title and abstract alone, a thorough examination of the main text was conducted to make an informed selection. Ultimately, 133 articles, constituting 85.25% of the initial pool, were excluded from the review. The common reasons for exclusion were as follows: (i) absence of older adults aged ≥65 years (76 articles), (ii) lack of endurance measurement (35 articles), (iii) participants with special conditions such as cancer (10 articles), (iv) protocol studies (7 articles), and (v) insufficient clarity regarding the age of participants (5 articles). Subsequently, 23 articles met the inclusion criteria and were selected for comprehensive review. The detailed process and outcome of the literature selection are visually presented in Figure 1.

3.1 Characteristics of Included Studies

The selected studies exhibited diverse settings, with thirteen conducted in clinics, hospitals, or acute care settings (involving 1,266 participants), six at universities or research centers (1,303 participants), three in community center settings like residential care or nursing homes (394 participants), and one conducted virtually at home (involving 100 participants). In terms of the mean age of study subjects, a prevalent mean age in the 60s was observed in 14 studies, followed by a mean age in the 70s in nine studies. The studies were geographically widespread, encompassing 15 countries, including the United States and Canada, indicating a global representation without bias towards any specific country.

Publication timelines varied, with the majority of studies published in 2019 (8 articles), followed by 2021 and 2022 (5 articles each), and 2018 and 2020 (2 articles each). A single article was published in 2023. Participants' health conditions in the selected studies ranged from healthy elderly individuals (7 articles) to those with specific health conditions such as COPD (5 articles), chronic heart failure, high-risk fall patients, kyphosis, acute coronary syndrome, post-traumatic stress disorder, rheumatoid arthritis, osteoporotic vertebral fracture, coronary artery bypass grafting, abdominal surgery, overweight and obese individuals, and

chronic kidney disease, each represented by one article.

3.2 Endurance Measurement Tools Used

Among the selected studies, various endurance measurement tools were employed. The 6 Minute Walk Test (6MWT) emerged as the most commonly used, featured in 12 out of 23 studies. Other frequently utilized tools included the Shuttle Walk Test, cycle ergometer, isometric contraction, 2 Minute Step Test, and the Timed Load Standing Test. Additionally, some studies employed less common tools such as stair climbing tests and bench/leg press.

3.3 Review of Most Commonly Used Tools

Detailed reviews were conducted for the two most commonly used endurance assessment tools, the 6MWT, and the Endurance Shuttle Walk Test. The

Table 1. Characteristics of included studies

Authors (Year)	Sample size	Age	Condition	Test
Zhou et al. (2023)[11]	90	69.25±10.85	Chronic heart failure	6 Minute Walk Test
Liu et al. (2022)[12]	66	71.7±4.94	Healthy elderly	Isometric contractions, 6 Minute Walk Test
Brach et al. (2022)[13]	249	77.4±6.6	Healthy elderly	6 Minute Walk Test
Auerswald et al. (2022)[14]	551	69.38±4.12	Healthy elderly	2 Minute Step Test
Stutz et al. (2022)[15]	24	65.8±4.9	Healthy elderly	incRMET
Nawrat et al. (2022)[16]	42	69.84±6.85	Risk of fall patients	6 Minute Walk Test
Aschauer et al. (2021)[6]	100	69.16	Healthy elderly	6 Minute Walk Test
Katzman et al. (2021)[17]	103	70.0±5.72	Patient with Kyphosis	Timed loading standing test
Liu et al. (2021)[18]	42	70.63±1.13	Healthy elderly	Isometric contractions
Beigiene et al. (2021)[19]	63	72.9±5.52	Acute coronary syndrome	6 Minute Walk Test
Majorski et al. (2021)[20]	38	66.9±7.46	COPD	6 Minute Walk Test
Hall et al. (2020)[21]	54	67.4±3.75	PTSD	6 Minute Walk Test
Kjærgaard et al. (2020)[22]	70	72.7±9.4	COPD	Shuttle Walk Test
Lange et al. (2019)[23]	74	69.62±2.45	Rheumatoid arthritis	Cycle ergometer
Barker et al. (2019)[24]	529	72. 14±9.09	Osteoporotic vertebral fracture	Timed loaded standing test, 6 Minute Walk Test
Højskov et al. (2019)[25]	326	65.05±17.5	Coronary artery bypass grafting	6 Minute Walk Test
Alison et al. (2019)[26]	111	69.04±7.50	COPD	Shuttle Walk Test
Hill et al. (2019)[27]	78	70.02 ± 8.40	COPD	Shuttle Walk Test
Cho et al. (2019)[28]	37	68.94±4.28	Healthy elderly	2 Minutes Step Test
Berton et al. (2019)[29]	20	69.4 ± 13.20	COPD	Cycle ergometer
Barberan et al. (2019)[30]	125	> 70	Abdominal surgery	Cycle ergometer
Galbreath et al. (2018)[31]	54	65.92±4.70	Overweight and obese	Bench/leg press, 6 Minute Walk Test
Hellberg et al. (2018)[32]	151	66.42±14.6	Chronic kidney disease	6 Minute Walk Test, Stair climbing, 30-STS Test

incRMET: 30-STS Test: 30 Second Sit to Stand Test, RCT: randomized controlled trial, COPD: Chronic obstructive pulmonary disease, PTSD: Post-traumatic stress disorder

6MWT, developed by the American Thoracic Society, assesses aerobic capacity and endurance, utilizing the distance covered in six minutes as the primary outcome measure. The Endurance Shuttle Walk Test, a constant-load exercise test, evaluates sustained sub-maximal exercise capacity.

3.3.1. Six–Minute Walk Test (6MWT)

The 6MWT, introduced by the American Thoracic Society in 2002, serves as a sub-maximal exercise test designed to evaluate aerobic capacity and endurance, offering valuable insights into an individual's functional capacity during physical activity.[33] Originally developed for patients with cardiopulmonary issues, the 6MWT has found applicability across diverse populations, including preschool children (2-5 years), children (6-12 years), adults (18-64 years), and elderly adults (65+), highlighting its versatility.[34]

3.3.1.1. Purpose and Assessment

The test involves walking for six minutes, and the distance covered becomes a key outcome measure, enabling comparisons of changes in performance capacity. It provides a holistic assessment of various physiological systems involved in physical activity, encompassing pulmonary and cardiovascular systems, blood circulation, neuromuscular units, body metabolism, and peripheral circulation. [34]

3.3.1.2. Equipment and Setting

While equipment variations exist among authors, typical components include a stopwatch, a measuring/trundle wheel to gauge distance covered, a 30-meter unimpeded walkway, and two cones marking the designated distance.[35] Optional tools such as a pulse oximeter for heart rate and SpO2 measurement, as well as the Borg Breathlessness Scale, may be employed.

3.3.1.3 Test Reliability

Test-retest reliability assessments on diverse populations, such as the study by Harada et al. (1999)[36] on elderly adults (n = 86; mean age = 75), reported excellent reliability with an r-value of 0.95. Similarly, Ries et al. (2009)[37] found excellent test-retest reliability for all participants with an ICC value of 0.98 when assessing patients with Alzheimer's disease.

3.3.2. Endurance Shuttle Walk Test (ESWT)

The Endurance Shuttle Walk Test (ESWT), introduced in 1999, is a straightforward and widely accepted field-based assessment designed to gauge the endurance exercise capacity of individuals with chronic obstructive pulmonary disease (COPD).[44] It was created to supplement the Incremental Shuttle Walk Test (ISWT) and employs an identical 10-meter shuttle course for consistent assessment. The key outcome measures include the distance covered (in meters, m) or the time taken (in seconds, s) to complete the test.[45]

3.3.2.1. Purpose and Assessment

The endpoint of the ESWT is determined by how

Table 2. Test-Retest Reliability of the 6MWT

Authors (year)	Population	Age (mean)	Sample size	Reliability
Harada et al. (1999)[36]	Healthy elderly	75	86	r = 0.95
Steffen et al. (2002)[38]	Healthy elderly	73±8	96	ICC = 0.95
Ries et al. (2009)[37]	Alzheimer disease	80.71 ±8.77	51	ICC = 0.98
Kennedy et al. (2005)[39]	Osteoarthritis	63.7±10.7	69	ICC = 0.94
Eng et al. (2004)[40]	Stroke	62.5±8.6	12	ICC = 0.99
Flansbjer et al. (2005)[41]	Chronic Stroke	58±6.4	50	ICC = 0.99
Fulk et al. (2008)42)	Acute Stroke	67.4 ±13.8	35	ICC = 0.86
Tappen et al. (1997)[43]	Alzheimer's Disease	84.7±3.94	33	ICC 0.97-0.99

6MWT: Six-minute walk test

Table 3. Test-Retest Reliability of the ESWT

Authors (year)	Population	Age (mean)	Number	Reliability
McKeough et al. (2018)[46]	COPD	70±8	66	ICC = 0.97
Quintino et al. (2021)[47]	Stroke	54±11	51	ICC = 0.93
Taylor et al. (2001)[48]	Chronic low back pain	48.2±14.2	44	ICC = 0.99

COPD: Chronic obstructive pulmonary disease, ESWT: endurance shuttle walk test

long the participant walks at a constant endurance speed. This test offers insights into an individual's capacity for sustained sub-maximal exercise, contributing valuable information to the assessment of endurance.

3.3.2.2. Equipment and Setting

The test requires eight tapes (or eight tracks on CDs), each pre-recorded with signals at different frequencies, providing a total of 16 walking speeds. Participants are instructed to walk up and down a 10-meter course, with cones set 0.5 meters from either end to prevent sudden changes in direction (Figure 1). A prescribed 90-second 'warm-up' speed precedes the test, with participants receiving prompts to increase their walking speed at subsequent signals. The detailed protocol ensures consistency and standardization in the administration of the ESWT, allowing for meaningful comparisons and reliable assessments of participants' endurance capabilities.

3.3.2.3. Test Reliability

In contrast to the 6MWT, there has been limited research assessing the reliability of the Shuttle Walk Test in older adults (those aged >65 years). Given this gap, relevant reliability studies conducted in different age groups have been incorporated into this study for informational purposes.

Ⅳ. Discussion

This systematic review stands as an unprecedented effort to delineate a comprehensive array of mobility assessment tests, shedding light on distinct tools employed to evaluate muscle and cardiopulmonary endurance among elderly individuals.

The primary objectives of our review were threefold: firstly, to succinctly summarize the latest available endurance assessment tests, secondly, to meticulously elucidate their characteristics, and lastly to synthesize the findings into a valuable reference guide, offering clinicians and researchers a nuanced understanding of the characteristics of each assessment test. We aimed to equip clinicians and researchers with a nuanced understanding of endurance measurement tools, facilitating astute and informed selections.

Endurance, as underscored earlier, is paramount for navigating daily activities and fostering healthy aging. Consequently, numerous evaluation tools have been developed to assess the endurance capacity of the elderly. However, the challenge persists in selecting the most apt measurement test, considering various criteria such as purpose, target population, content validity, ease of usage, suitability of scale, and format.

Initiating the endurance assessment process mandates a clear definition of the primary purpose(s) guiding the evaluation of an elderly individual's endurance.[49,50] We posit that the choice of an endurance assessment test should align with the specific objectives set for the evaluation. Guyatt et al. (2018)[51] highlight three overarching purposes for assessment tools: discrimination between subjects, prognostication, and evaluation of changes over time. Notably, endurance assessment can traverse three critical domains: evaluation of muscle performance, integrity, and transfer. Consequently, outlining the specific domains for analysis becomes imperative. In our review, we provide a general description of the identified tests' purposes, revealing that 8 tests were crafted explicitly for endurance evaluation. Among these, the 6 Minute

Walking Test (6MWT) took precedence in 12 articles, followed by the cycle ergometer and the shuttle walk test, each mentioned in 3 articles. Several factors contribute to the widespread usage of the 6MWT. To mention some main factors, the 6MWT replicates the functional demands of daily life, offering a real-world simulation of activities that older adults typically engage in. Its simplicity and adaptability contribute to global popularity, requiring minimal equipment and facilitating use in diverse healthcare settings.[35] Inclusivity allows assessment across various health conditions, making it versatile in clinical settings. Extensive research confirms its reliability, offering a consistent and dependable measure for tracking changes over time and assessing intervention impacts on endurance.[36,37,38,39,40,41,42,43]

While aligning measurement selection with the initial evaluation purposes is crucial, additional considerations warrant careful examination. The chosen measurement should not only align with the assessment objectives but also demonstrate appropriateness for the target population. In the case of evaluating endurance in elderly individuals, the selected test must have a documented history of application among a similar demographic. However, acknowledging the potential impact of various factors on walking patterns, as highlighted by Berton et al. (2019)[29], remains integral.

Given the extensive array of mobility assessment tests, a succinct summary table serves as a valuable consumer's guide. As articulated by McDowell et al. (2007)[52], the quest for a universal perfect index is futile, given the diverse nature of diseases, individuals, and applications. Therefore, furnishing clinicians and researchers with adequate information becomes pivotal for achieving standardization and sensibility. In light of the methodological classifications existing among measurement tests, we propose a summary of studies in Table 1. This guide delineates key information about the purpose, targeted population, and settings of each test. While all mentioned tests are applicable for assessing the healthy condition of older adults and geriatric care, some may also find utility in evaluating the endurance of older adults with specific conditions.

In summary, this systematic review provides a comprehensive overview of the existing literature on assessments for measuring muscle and cardiopulmonary endurance in older adults, with a particular focus on individuals aged 65 and above. The escalating global demographic shift toward an aging population accentuates the urgency of promoting healthy aging, emphasizing the pivotal role of maintaining physical resilience, specifically in terms of endurance. As clinicians and researchers navigate the abundance of available assessment tools, this review aims to serve as a valuable reference guide. The detailed characteristics of each assessment test, including its purpose, target population, and settings, have been synthesized to facilitate informed decision-making.

To give some recommendations for researchers and practitioners, it is imperative to use a valid and reliable test method, such as the 6-minute walk test or the Shuttle walk test, which is imperative for assessing endurance in elderly adults. Additionally, conducting tests in an environment closely mirroring daily activities is crucial to ensure simplicity and easy administration for practitioners. From the patient's perspective, especially among elderly adults, selecting a test with minimal burden and a low likelihood of adverse events is critical. This characteristic is particularly crucial when working with older adults, as many may have varying levels of physical ability. Future studies should examine the correlation between the 6MWT and the other commonly used assessment methods.

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